SCH4C1 VSEPR THEORY, POLAR COVALENT BONDS AND POLAR COVALENT MOLECULES WS-11

1. Generally speaking, what is the difference between the terms *intramolecular* and *intermolecular* forces of attraction? *Intramolecular forces involves the attractions between atoms in a molecule (bonds) whereas intermolecular forces involve attractions between molecules themselves.*

2. Is a covalent bond considered to be an *intramolecular* or an *intermolecular* force of attraction? *A covalent bond is considered to be an intramolecular force of attraction.*

3. What is the difference between a:
   a. Non-polar covalent bond and a polar covalent bond? *In a non-polar covalent bond, the electrons are shared equally whereas in a polar covalent bond, the electrons are shared unequally.*
   b. Non-polar covalent molecule and a polar covalent molecule? *A non-polar covalent molecule is one in which the bond dipoles cancel one another.*

4. The length of a covalent bond between two identical atoms is equivalent to the sum of their atomic radii. *(Atomic radius is the distance from the nucleus to the outermost electron.)*

   For example, the atomic radius for hydrogen is 37 pm and that for fluorine is 64 pm.

   Based on the above information, what would be the length of the bond for H_2, a non-polar covalent molecule? *The length, based on the above information, should be 37pm+37pm or 74 pm. Although not shown here, this matches the experimentally determined bond length for hydrogen.*

   Based on the above information, what would be the length of the bond for F_2, another non-polar covalent molecule? *The length, based on the above information, should be 64pm + 64 pm or 128 pm. Although not shown here, this matches the experimentally determined bond length for fluorine.*

   What then, would be the theoretical length for the H-F bond? *The theoretical bond length should be 101 pm.*

   Experimental evidence shows that the bond length for HF is 92 pm. What gives? Hmmmm....
   HF is a very polar covalent bond. Based on this fact alone, how might we explain the difference between the theoretical and the actual bond lengths? That is, what would make the bond length shorter than predicted? *HF forms a polar covalent bond. This means that the hydrogen atom is slightly positively charged whereas the fluorine atom is slightly negatively charged. Opposite charges attract... The atoms are then drawn closer together making the bond length shorter.*

5. There are three types of intermolecular forces of attraction: *dispersion, dipole-dipole, and hydrogen bonding*. What are the differences between these three? *Dispersion forces are weak forces of attraction set up by small temporary dipoles. Dipole-dipole forces of attraction occur when there are permanent dipoles. Hydrogen bonding is a special extension of dipole-dipole forces of attraction. They occur when hydrogen is bonded to either nitrogen, oxygen or fluorine.*

6. For each of the following substances: *(see a separate solutions page)*
   i. determine if the bonds are polar
   ii. state and sketch the shape of the molecule
   iii. indicate whether or not the molecule is polar
   iv. indicate the type of intermolecular force that would predominate (rule)

F_2	SCl_2	CH_2O	NO_3^{1-}	PCl_4F	Br_2	PH_3	NBr_3
CCl_4	H_2Se	NO_2^{1-}	BrF_3	BrF_5	SCl_4	$SnCl_5^{1-}$	NH_4+

7. Molecular nitrogen, N_2, has a boiling point of -196°C while oxygen, O_2, has a boiling point of -183°C.
   a. Identify each molecule as being polar or non-polar. *Both of these molecules are non-polar.*
   b. Are the intermolecular forces of attraction dispersion, dipole, or hydrogen bonding? *Since both of these molecules are non-polar, the intermolecular forces present are those of dispersion.*
   c. Account for the differences in their boiling points. *The mass of a nitrogen molecule is 28u while that for oxygen is 32u. The slightly larger mass means that there are more electrons available which could set up the temporary dipoles that lead to more dispersion forces.*

8. The boiling point for nitrogen monoxide is -157°C.
   a. Is this molecule polar or non-polar? *This molecule is polar covalent.*
   b. Account for the fact that its boiling point is higher than those of its respective elements. *This molecule, like the above elements in question 7, is a linear molecule. However, it is a polar molecule and thus has dipole-dipole forces of attraction present. These forces are stronger than dispersion forces and thus the molecule have a higher melting point.*

9. Which would have the higher boiling point: chlorine gas or iodine monochloride? Explain. *Both are linear molecules. However, iodine monochloride is slightly polar and thus it has a higher boiling point (dipole-dipole forces of attraction).*

ANSWERS TO THE REMAINING QUESTIONS CAN BE FOUND ON A SEPARATE ATTACHMENT.

10. Dry ice, CO_2, is held together by what type of intermolecular forces? How does this account for the fact that dry ice readily changes from a solid to a gas?

11. Vapour pressure is the pressure that vapours would exert in a container. A substance with a high vapour pressure would evaporate more readily than one with a low vapour pressure. Which of the following substances would you expect to have the lowest vapour pressure: NH_3, PH_3, CH_4?

12. Predict which of the following substances in each pair will have the highest melting point?

   a. CS_2 or CCl_4
   b. Cl_2 or F_2
   c. SiO_2 or CO2
   d. $CHCl_3$ or CF_4
   j. BF_3 or P_4
   f. HI or KI
   g. Na_2O or H_2O
   h. CH_4 or NH_3
   i. CaF_2 or HF

13. Rank each of the following from strongest to weakest intermolecular forces:

   a. He, NH_3, NF_3, NaCl
   b. HF, F_2, FCl

14. Identify and explain which molecule (from each pair) would have the highest melting point.

   a. CS_2 vs CCl_4
   b. HI vs HBr
   c. Cl_2 vs F_2
   d. Na_2O vs H_2O
   e. CH_4 vs NH_3
   f. $CHCl_3$ vs CF_4